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Aerial application of mexacarbate and stabilized pyrethrins on Douglas-fir tussock moth populations

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The effectiveness of mexacarbate and stabilized pyrethrins formulations was tested in 1972 on field populations of Douglas-fir tussock moth larvae (*Orgyia pseudotsugata* [McDunnough]), in eastern Washington and Oregon forests of Douglas-fir (*Pseudotsuga menziesii* var. *glauca* [Beissn.] Franco), and true fir (*Abies* sp.). Mexacarbate was applied at the rates of 0.15 lb/gal/acre (68.04 g/3.785 l/0.404 ha) and 0.30 lb/gal/acre (136.08 g/3.785 l/0.404 ha), and the pyrethrins were applied at the rate of 0.05 lb/½ gal/acre (22.68 g/1.89 l/0.404 ha). Mortalities of Douglas-fir tussock moth larvae ranged from 51 to 87 percent in the mexacarbate-treated plots and from 46 to 60 percent on the pyrethrins-treated plot (two applications). Inadequate dosages and low, variable spray deposits were the major factors reducing the field effectiveness of the insecticides in suppressing Douglas-fir tussock moth larval populations.

Oxford: 145.7x18.77 *Orgyia pseudotsugata* [–453–414.12 Mexacarbate + 453–414.12 Pyrethrum]
Retrieval Terms: Tussock moth; Douglas-fir; insecticides; mexacarbate; pyrethrins; performance tests; Pacific Northwest.

Populations of Douglas-fir tussock moth (DFTM) (*Orgyia pseudotsugata* [McDunnough]), a major defoliator of Douglas-fir (*Pseudotsuga menziesii* var. *glauca* [Beissn.] Franco) and true fir (*Abies* sp.) periodically show rapid, dramatic population increases and decreases in Western North America. Major outbreaks have been recorded every decade in western fir forests since 1928. Generally, outbreaks collapse naturally at the end of the second, or more commonly, the third year through the action of biotic factors, primarily by parasites and a nucleopolyhedroses virus.[1] These natural control factors may not become effective, however, until the late stages of larval development of the insects, or the decline phase of the outbreak, or both. By then severe defoliation of the forest and some tree mortality may have occurred.

Before 1972, outbreaks were controlled by a combination of virus, parasites and predators, and aerial applications of DDT applied at the rate of 0.75 to 1.0 lb/acre (340.19 g to 453.9 g/0.404 ha).[1] In 1972, the U.S. Environmental Protection Agency (EPA) banned the use of DDT for all but a few minor instances. At the time we did this study (1972), no insecticide was registered with EPA for control of the DFTM.

Also in 1972, a dramatic growth of DFTM populations in the Douglas-fir-true fir forests of eastern Oregon and Washington provided an opportunity to test two relatively nonpersistent insecticides for the control of DFTM: mexacarbate, a carbamate insecticide, and a stabilized formulation of pyrethrins. The stabilized formulations of pyrethrins will persist for at least 4 hours in sunlight,[2] and mexacarbate has a residual life of at least 2 days under field conditions.[3] We found that both chemicals can effectively suppress DFTM populations, although results were affected by inadequate dosages and low, variable spray deposits.

MATERIALS AND METHODS

The field tests were divided into two parts. In the first part, mexacarbate and stabilized pyrethrins were sprayed on 3rd and 4th instars on plots near Oroville and Riverside, Washington. In the second part, mexacarbate was sprayed on 5th and 6th instars and some pupae on three plots near LaGrande, Oregon. To monitor natural mortality in DFTM populations, particularly that due to virus, we set up three check plots at least 2 air miles (3.22 km) from those selected for treatment. The check plots were protected from possible spray drift by ridges.

All study plots, which ranged from 300 to 500 acres (121 to 202 ha) in size, were in Douglas-fir-true fir stands infested by DFTM. Each plot had four clusters of 10 host trees selected for sampling DFTM populations. Sample trees were 30 to 40 ft (9.14 to 12.19 m) tall, were open grown and not sheltered by taller trees. Boundaries of each plot selected for insecticide treatment were marked with colored ribbons.[4]

A Bell 47G-3 helicopter,[5] equipped with conventional boom and nozzle spray system, was used to apply the insecticides from a flying height of 50 ft (15.24 m) in 100-ft (30.40 m) swath widths. The pyrethrins were delivered through 29 nozzles equipped with No. 80015 tips with a spray nozzle of 40 psi (28,122.80 kg/m^2). Mexacarbate was sprayed through 22 nozzles equipped with No. 8003 tips with pressure of 60 psi (42,184.20 kg/m^2). Insecticide applications began in the early morning when the wind was downslope and less than 6 mph (9.66 km/hr).

Washington Tests

The stabilized pyrethrins test was done on a 345-acre plot near Oroville, Washington. The formulation contained 0.1 lb/gal (45.36 g/3.785 l) AI (1.44 percent pyrethrins) in an oil carrier consisting of 5.6 percent petroleum distillate, 90.8 percent heavy mineral oil, and 3.6 percent inert ingredients (stabilizers). To each gallon, 3.785 g each of fluorescent tracer (Fluoranthene) and an oil red dye were added to help assess deposit. Two applications were made, 7 days apart, each at the rate of 0.05 lb/½ gal/acre (22.68 g/1.89 l/0.404 ha). The first application was made June 22, 1972 against DFTM larvae in the 2nd, 3rd, and 4th instars; the second application was made June 29, 1972 against larvae in 3rd and 4th instars.

Mexacarbate was applied on June 27, 1972 against 3rd and 4th instar DFTM larvae on a 400-acre (161.1-ha) plot near Riverside, Washington. The formulation consisted of 1.5 lb (680.39 g) mexacarbate in a gallon (3.785 l) of Dowanol TPM mixed 1:9 ratio with fuel oil No. 2 to yield 0.15 lb AI/gal (68.04 g AI/3.785 l). To each gallon (3.785 l) of this formulation, 3.785 g of the fluorescent tracer (Rhodamine B Extra Base) were added.

DFTM larval populations were sampled 24 hours before treatment and again 4 days later by using a variant of the method described by Mason.[6] Four 15- to 18-in (38- to 45.72-cm) twigs were cut with a pole pruner from the midcrown of the study trees for the prespray sample, and eight twigs of similar size were cut for the postspray sample. All DFTM larvae were counted, and the foliated length and width of each sample twig were measured.

In the pyrethrins experiment, the first postspray sample of the DFTM population also served as the prespray sample for the second application made 3 days later. DFTM populations of the study trees were sampled again 4 days after the second application.

Oregon Tests

Three study plots in northeast Oregon, each about 300 acres (121.2 ha) in size and containing mostly 5th and 6th instar DFTM, were sprayed with mexacarbate. The mexacarbate formulation contained DuPont Oil Red dye for deposit assessment and was applied at the rates of 0.15 lb/gal/acre (68.04 g/3.785 l/0.404 ha) to two plots and 0.30 lb/gal/acre (136.08 g/3.785 l/0.404 ha) to the third.

DFTM populations on the mexacarbate-treated plots and nearby check plot were sampled 24 to 48 hours before treatment and again 4 to 6 days after treatment. The sampling procedure was similar to that used in the Washington experiment.

Spray Deposit Assessment

In the Washington test, spray deposit was sampled from aluminum plates and white Kromekote cards placed under and adjacent to each sample tree, and from foliage samples collected at the midcrown of every sample tree. Only aluminum plates and white Kromekote cards were used to sample spray deposit in the Oregon test. Amount of spray deposit was determined by fluorometric analysis.[7] Deposit on the plates was converted to gal/acre, and deposit removed from the foliage, was converted to μg AI/100 needles. Droplet volume median diameters (VMD's) and densities were determined from the spray collected on the white cards. The VMD is the theoretical center of the spray droplet size spectrum, i.e., half of the spray mass is in droplets larger than the VMD and half in droplets smaller than the VMD. Spray atomization was determined by the drop-size spectra method.[8]

Data Analysis

The field effectiveness of the various treatments in reducing DFTM populations was evaluated by comparing DFTM populations responses: (a) pre- and postspray population densities for each tree, cluster of trees, and study plot; (b) mortality of DFTM for each tree, tree cluster, and study plot among the various treatments; and (c) insect mortality and the various spray deposit data for each insecticide and spray plot.

All insect counts were adjusted to a common unit of branch area, i.e., 1000 sq. in. by a computer program. Pre- and postspray DFTM population densities and mortalities and their standard errors were calculated (*table 1*).

The pyrethrins treatment was examined as three separate treatments: two single applications and a double application. One set of "t-test" analyses compared the pre- and postspray DFTM population densities of the first pyrethrins application. Another set used postspray DFTM population density from the first applications as the prespray population of the second pyrethrins application, and compared it with the postspray population density after the second pyrethrins application. The third set compared the prespray population density of the first pyrethrins application with the postspray population density of the second application as if there were just two sets of samples for a double application treatment (*table 1*).

A full screen analysis computer program called WINNOW[9] was used to relate insect mortality to 10 variables: (a) deposit on foliage; (b) deposit on aluminum plates placed in the forest openings nearest the sample trees (DEPAO); (c) deposit from aluminum plates which were placed in the forest openings minus the deposit from plates placed beneath the canopy of sample trees; (d) number of drops on cards placed in forest openings nearest sample trees (DDCO); (e) number of drops on cards placed in the open minus the droplet density on cards placed beneath the canopy of sample trees; (f) insecticide treatment (ITC); (g) area (plot number); (h) DDCO x ITC; (i) DDCO x Area; and (j) DDCO x DEPAO.

Six computer runs were made to maximize the sample size for each set of variables. These runs could not be treated as independent because each was made on a partially but not completely different subset of the data base. The "best" regression was the one identified by the highest probability of F for rejection of the hypotheses that the regression line is not significantly better than the mean value.

RESULTS AND DISCUSSION

Prespray populations of DFTM varied widely from plot to plot and tree to tree in the study areas (*table 1*). The high variation in DFTM populations and coverage of the target (study) areas by the insecticides are responsible for the high standard errors associated with the population density and mortality estimates. All mortality estimates, except those for the 0.15 lb (68.04 g) mexacarbate treatments applied in Oregon (plots 5 and 7) were encompassed by confidence bands calculated for the level of 95 percent probability.

Mexacarbate Treatments

Mexacarbate applied at 0.15 lb AI/gal/acre (68.04 g AI/3.785 l/0.404 ha) against DFTM populations in the 3rd and 4th instars on plot 3 in Washington produced an estimated mortality of 87 percent, and an 85 percent reduction in a population consisting mainly of 5th and 6th instars and some pupae on plot 5 in Oregon. In contrast, the same application on plot 7 in Oregon reduced population by only 52 percent. Mexacarbate applied at 0.30 lb AI/gal/acre (136.08 AI/3.785 l/0.404 ha) on plot 6 reduced population by 62 percent—the same percentage as the estimate of natural mortality on the check plot in Oregon.

The results clearly suggest the importance of careful spray application under proper weather conditions. Plots 3 and 5 were treated early in the morning with a slight down-slope wind under favorable weather conditions. The highest mortality from all the treatments was obtained on these plots. The spray coverage was excellent (*table 1*). In contrast, plot 6 was sprayed in the late morning when up-slope windspeed greatly exceeded the recommended threshold of 6 mi/h (9.66 km/h) for aerial application efficiency. As a result, spray coverage on plot 6 was poor. Only an average of 12 percent of the emitted dosage and about 8 droplets/cm^2 were recovered from the plates and cards on plot 6 (*table 1*).

Pyrethrins Treatment

Mortalities achieved by the two-stage pyrethrins treatment against the 3rd and 4th instars on plot 1 were 60 percent after the first application of 0.05 lb AI/½ gal/acre (22.68 g AI/1.89 l/0.404 ha), and 46 percent after the second application 7 days later. Larval mortalities in the check plot were 10 and 44 percent respectively for the corresponding time periods. The total DFTM mortality for the pyrethrins

treatment was about 78 percent; corresponding mortality estimate in the check area was 49 percent (*table 1*).

At first glance, the results of the pyrethrins treatment seem disappointing, and especially so because pyrethrins are three and one-half times more toxic than mexacarbate at the LD_{90} level in laboratory tests.[10] Two explanations are possible. Degradation may have considerably reduced the toxicity of the pyrethrins droplets by the time they reached the DFTM. Spray coverage of the target area was poor, as indicated by the amount of pyrethrins spray that reached the aluminum plates and white cards and foliage of the sample trees. Our estimates of deposit on the aluminum plates were 0.08 gal/acre (0.303 l/0.404 ha) and 0.06 gal/acre (0.227 l/0.404 ha) for the two pyrethrins applications, giving a low total of about 0.14 gal/acre (0.530 l/0.404 ha), or about 14 percent of the total emitted dosage of 1 gal/acre (3.785 l/0.404 ha) (*table 1*).

Comparison of Results

Results of the Washington and Oregon field tests can be evaluated in two ways: (a) by comparing amount of insecticide deposited on the plates and cards with the resulting apparent mortality of DFTM population; and (b) by comparing mortality obtained in an open-ground airport test at Corvallis with the Washington and Oregon tests. In the airport test, DFTM larvae were placed on potted Douglas-fir trees 1½ ft (30.5-46 cm) tall and in petri dishes at selected sampling stations. They were, therefore, much more exposed to insecticide applications than were larvae under natural forest conditions. For comparable dosage rates, spray deposit values, and swath widths, insect mortality was higher in the airport tests than in the Washington and Oregon tests. Mexacarbate applied at the rate of 0.15 lb/gal/acre (68.04 g/3.785 l/0.404 ha) in the airport test resulted in over 99 percent mortality with a mean spray deposit of 0.057

Table 1—*Insect population density and mortality and spray deposit estimates in insecticide tests against the Douglas-fir tussock moth in Washington and Oregon, 1972*[1]

Plot number and location	Treatment dosage	Population density		Mortality	Spray deposits on . . .		
		Prespray	Postspray		Foliage	Aluminum plate[3]	Kromekote card[3]
	lb/acre	*Insect/1000 sq. in. of branch area*		*Percent*	*µg AI/100 needles*[2]	*Gal/acre*	*Drops*
Washington:		Pyrethrins					
1 (Oroville)[4]	0.05	51.84(22.91)	20.71(40.9)	60.04(35.90)	5.42(9.79)	.08(.06)	11.08(7.66)
2 (Oroville)	Control	37.10(10.76)	33.28(32.20)	10.30(46.70)	–	–	–
1 (Oroville)[5]	0.05	20.72(12.58)	11.17(19.00)	46.06(18.85)	–	.06(.05)	–
2 (Oroville)	Control	33.52(9.80)	18.64(22.50)	44.40(23.50)	–	–	–
1 (Oroville)[6]	0.1	51.84(22.91)	11.17(19.00)	78.45(10.31)	–	–	–
2 (Oroville)	Control	37.10(10.76)	18.64(22.50)	49.76(41.43)	–	–	–
Washington:		Mexacarbate					
3 (Riverside)	0.15	81.57(61.29)	10.50(13.09)	87.13(17.69)	7.88(4.33)	.49(.16)	73.43(22.40)
4 (Riverside)	Control	7.60(3.57)	3.67(6.24)	51.71(11.83)	–	–	–
Oregon:							
5 (Elk)	0.15	13.49(3.84)	1.98(4.05)	85.29(9.89)	–	.69(.27)	64.41(25.07)
6 (Ridge)	0.30	45.26(7.25)	17.34(14.48)	61.69(14.40)	–	.12(.12)	7.71(4.97)
7 (Farmhouse)	0.15	19.22(1.05)	9.27(.77)	51.85(2.84)	–	[7].32(.16)	29.35(18.34)
8 (Elk)	Control	8.35(1.67)	3.20(2.14)	61.68(10.77)	–	–	-

[1] Values in parentheses are standard errors of the mean.

[2] Amount of dye recovered.

[3] Placed in openings in forest canopy nearest study trees.

[4] First application.

[5] Second application. Spray deposits sampled on aluminum plates only.

[6] Two applications compare the prespray population density of the first application with the postspray population density of the second application. No spray deposits.

[7] Based on treatment of 20 trees only.

gal/acre (0.216 1/0.404 ha), while pyrethrins applied at the rate of 0.05 lb/½ gal/acre (22.68 g/1.89 1/0.404 ha) resulted in a 69 percent mortality with a mean deposit of 0.137 gal/acre (0.519 1/0.404 ha).[11]

Laboratory tests, made after these field tests were completed, indicated that 0.31 lb/acre (140.61 g/0.404 ha) of mexacarbate and 0.09 lb/acre (40.82 g/0.404 ha) of pyrethrins were required for an LD_{90} effect on DFTM populations in the late larval stages.[3] On the basis of the laboratory tests, it appears that another major reason for the apparent poor field performance of the insecticides was the inadequate dosage rates used in these field tests. Pyrethrins were applied in two applications of 0.05 lb/acre (22.68 g/0.404 ha). The actual deposits were 0.004 lb/acre (1.818/0.404 ha) for the first application and 0.003 lb/acre (1.36 g/0.404 ha) for the second. Although combined dosage rates for both pyrethrins applications totaled 0.1 lb/acre (45.36 g/0.404 ha), the low field persistence of pyrethrins would render the cumulative dosage and subsequent deposit inconsequential, particularly since the second pyrethrins application was made 7 days after the first.

Mexacarbate applied at 0.15 lb/acre (68.04 g/0.404 ha) was an inadequate dosage rate as the rate of 0.30 lb/acre (136.08 g/0.404 ha) approximated the amount of deposit required for the LD_{90} effect as determined by the laboratory tests. The actual deposit for the mexacarbate treatments ranged from 0.104 lb/acre (47.17 g/0.404 ha) for plot 5 to 0.018 lb/acre (8.16 g/0.404 ha) for plot 6. Unfortunately, data on field effectiveness of 0.30 lb/acre (136.08 g/0.404 ha) dosage of mexacarbate applied on plot 6 was obscured by poor spray coverage.

CONCLUSIONS

Mortality estimates of DFTM populations varied from 51 to 87 percent in the mexacarbate-treated plots and from 46 to 60 percent in the pyrethrins-treated plots. High standard errors of the mean were associated with these estimates due to much variation in prespray populations and spray coverage. Full screen regression analyses, which related insect mortality to 10 variables, gave evidence of poor treatment coverage as accountable for most of the variability in DFTM mortality. "Insecticide treatment," however, was not included in the "best" regression in any runs. Its interaction with spray droplet density was included in three or four "best" regressions, however. This would tend to support the hypothesis that either all of the insecticide treatments were of equal efficacy, or that the tests were confounded by nonequivalent application procedures.

Results suggest that area may be an important variable. The significance of this may be that no comparison can be made among the insecticide treatments because they were not applied under comparable geographic, forest stand, and meteorological conditions. This suggests inadequate treatment replication in the experimental design.

Laboratory tests indicated that inadequate dosage rates were another major reason for the apparent poor field performance of the insecticides. Late instar application in Oregon, rapid degradation of the pyrethrins, and unequal weather conditions were other factors affecting results.

NOTES

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[5] Trade names and commercial enterprises or products are mentioned solely for information. No endorsement by the U.S. Department of Agriculture is implied.

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